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High Rise Buildings

White paper

January 2017

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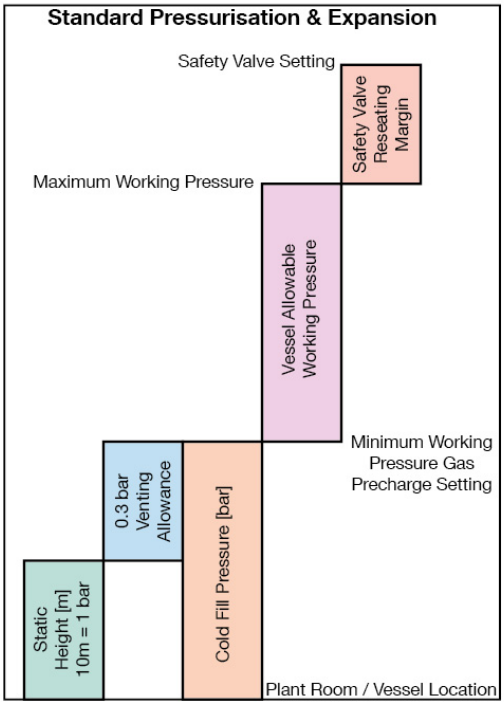
It seems unusual in our industry to consider all the aspects of a system working together, even though this is what we are aiming for. The aim of this white paper is to promote 'Joined up Thinking'.

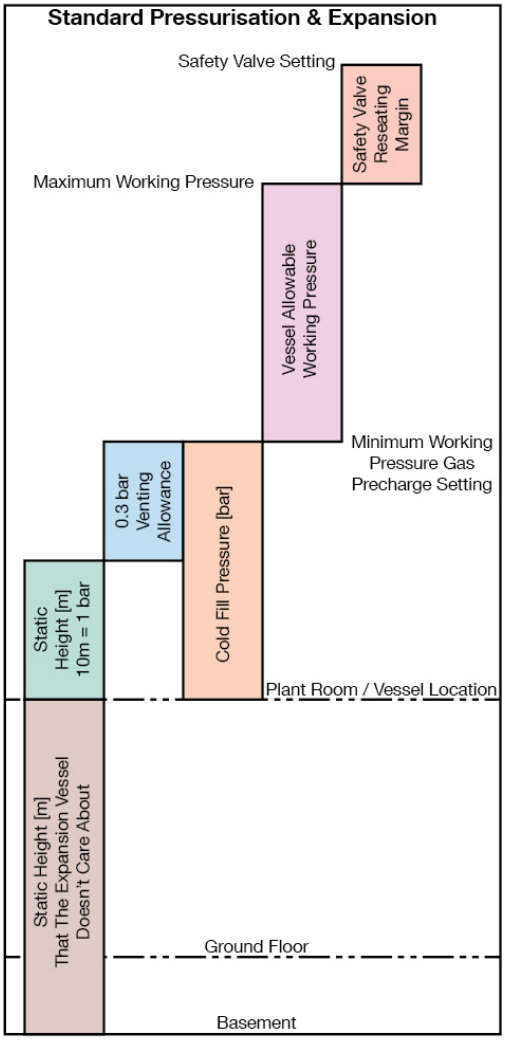
Water

Water is strange stuff, the only substance that gets bigger (expands) as it gets hotter and as it gets colder, when viewed from a 4°C starting point.
Water is not compressible, for practical purposes, and as a result the 'pressure' that we see in water systems comes from the physical weight of water and the associated equipment for moving it around.

Static Height

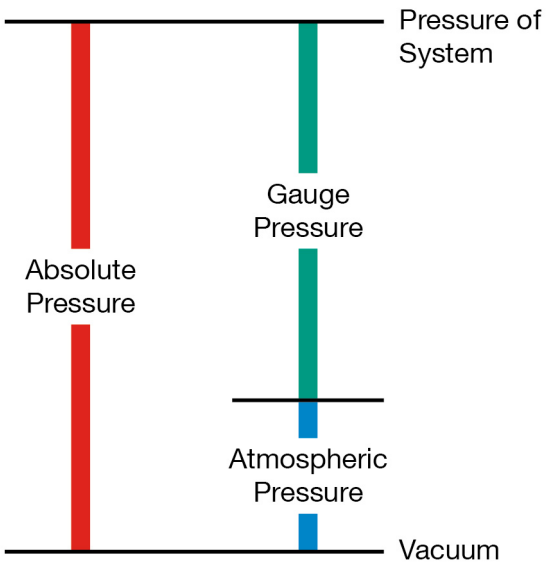
The physics of Static Height are easily simplified in our industry, for practical purposes 10m of vertical height on a water system relates to a 1 bar pressure at the bottom, to have 0 bar at the top. We can think in terms of the sea, easy to swim and float on the top, difficult to exist on the bottom of the sea with lots of water above. In terms of physical engineering, a submarine to go 10m underwater in a swimming pool is the same submarine that can go 10m underwater in the Atlantic. Weight of water is the key to understanding here, it does not matter if a pipe is 15mm diameter, 1000mm diameter or 10,000mm diameter, for a 10m system height, 1 bar is the water pressure (weight) at the bottom with no pressure (weight) at the top.





Gauge pressure vs Absolute pressure

When we talk about pressure, as an industry we normally default to gauge pressure (as in the above static height example). In real terms the universe is geared to work in terms of absolute(a) pressure, where Outer Space is taken as being 0 (zero) bar(a), as a result on planet earth we live at 1 bar(a).
Practically, however, a plumber takes a pressure gauge out of a box, and without it being connected to anything, they expect it to show 0 bar. In this way we are talking about gauge pressure, 0 bar(g).



Circulation Pump

A circulation pump is designed to do one thing, move water around a system at the required flow rate. To do this it has to effectively push, and sometimes pull, the water. Back to Physics again, push and pull are simply forces, that affect the perceived pressure of the water at that point. This is also referred to as 'pump head'.

'Pump Head' is what is required to push the water round a system, not to overcome the static height, it is there to overcome frictional resistance of the system in terms of pressure loss through heat exchangers, pipework, fittings, emitters and valves. This way, a system with a 200 meter static height does not need a 'Pump Head' of 20 bar.

Neutral Point

The neutral point is the location in the system where the static pressure is unaffected by the operation of the circulating pump. Effectively the circulating pump discharge pressure (or the pump suction pressure) has no bearing on the pressure seen at that point regardless of if the pump is running or not (on or off).

Expansion Vessels

A little known fact is that the physical position of expansion equipment forces the neutral point to that location. This then will always affect the way that the circulation 'pump head' impacts on the pressures of the wider system, either moving the 'pump head' more to the discharge side or to a more even split across the pump

Another little known fact is that for systems above 60m in static height, the setup and commissioning of the expansion vessel is more complicated. The vessel diaphragm cannot see a pressure differential of more than 6 bar, in favour of the gas side, during operation and commissioning. In effect a gas overpressure, of 6 bar or more, pushes the diaphragm out of the water connection and will damage the

rubber membrane. As a process, the water pressure and gas pressure must be incrementally stepped up during commissioning to prevent this happening. This takes time, experience and care to achieve successfully. Failure to do so will cause damage, delays and most importantly, cost.
A final little known fact is that expansion vessels are calculated based on 'efficiency'. This is taken as the smaller of two figures, either the design efficiency of the vessel or the system efficiency. This is a relationship between the maximum working pressure and minimum working pressure (all taken as absolute pressures). This relationship is:

$$\textit{System Efficiency} = \frac{\text{Pa (max X) - Pa (min X)}}{\text{Pa (max X)}}$$

The real implications of this, however, come into effect with taller and taller systems. A 2 bar differential between maximum (3 bar) and minimum (1 bar) operating pressures on a 10m system result in a 50% system efficiency:

$$\textit{System Efficiency} = \frac{\text{Pa (max 3+1) - Pa (min 1+1)}}{\text{Pa (max 3+1)}} = 0.5 \qquad = 50\%$$

**Pressures adjusted from 'gauge' to 'absolute' by adding 1 bar*

However the effects on taller systems are dramatic, assuming a 70m system with a 2 bar differential between maximum (9 bar) and minimum (7 bar) pressures:

$$\textit{System Efficiency} = \frac{\text{Pa (max 9+1) - Pa (min 7+1)}}{\text{Pa (max 9+1)}} = 0.2 \qquad = 20\%$$

**Pressures adjusted from 'gauge' to 'absolute' by adding 1 bar*

The effects on even taller systems are more dramatic, assuming a 120m system with a 2 bar differential between maximum (14 bar) and minimum (12 bar) pressures:

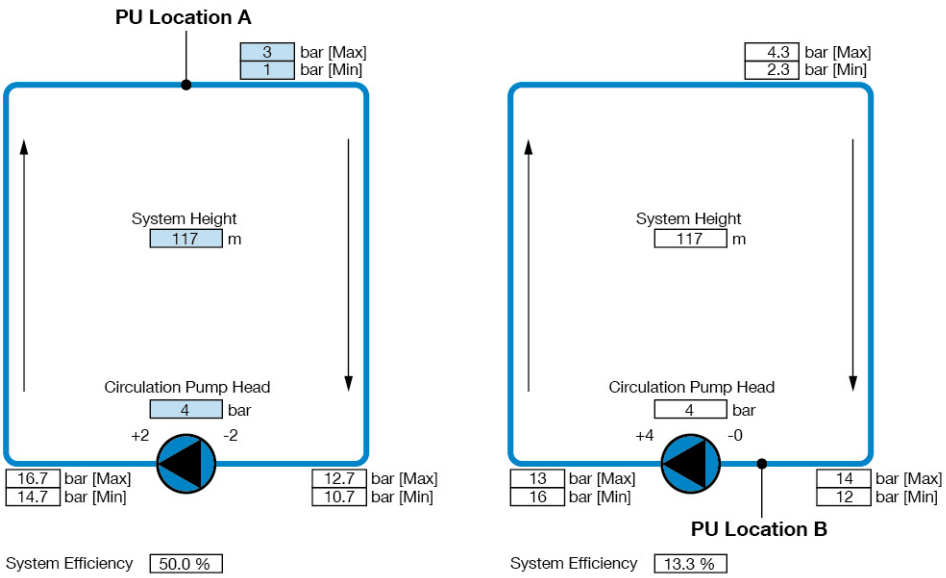
$$\textit{System Efficiency} = \frac{\text{Pa (max 14+1) - Pa (min 12+1)}}{\text{Pa (max 14+1)}} = 0.133 \qquad = 13.3\%$$

**Pressures adjusted from 'gauge' to 'absolute' by adding 1 bar*

Therefore the higher a system is, with the expansion vessel at the bottom of the system, the less efficient a system can be.

Location, Location, Location

The real interest then comes from the choice of installation location on tall systems, especially on systems with typically more than 60m of static height.



The example below shows the effects on the circulating 'pump head', the effects on static height and the resulting system pressures. It is clear to see how these technologies and principles work together.

The example shows:

Expansion Vessel Location - Top of System (A)	Expansion Vessel Location - Bottom of System (B)
Cost efficient	Higher cost - equipment, maintenance & commissioning
'Pump Head' evenly distributed across pump	'Pump Head' all moved to pump discharge
Overal system pressure lower	Overall system pressure higher
System efficiency maximised	System efficiency compromised
Associated pressurisation Unit simplified (low pressure)	Associated pressurisation unit complicated (high pressure)
Associated vessel size/space required minimised	Associated vessel size/space required minimised

Knock on effects

With the expansion equipment sited at the top of the system the overall running pressure can be properly controlled, with the 'pump head' being efficiently applied and balanced. The associated pressurisation equipment can be kept at low pressure, and as a result becomes standard equipment, serviceable and reliable.

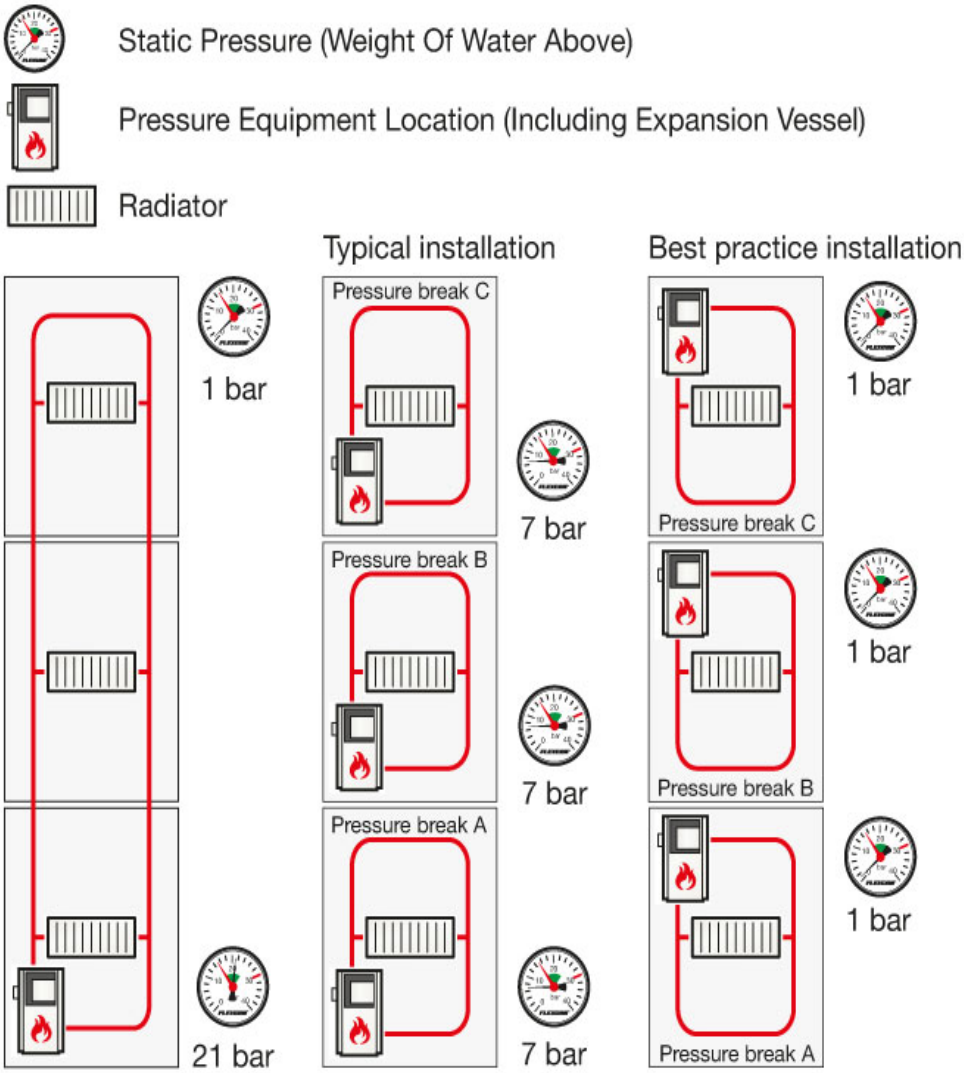
Higher pressure pressurisation equipment typically uses DOL (Direct On-Line) pumps, the run time of these pumps generally is very short. As a result the extra cost of VSD (Variable Speed Drive) is often not accepted, sadly with greater operating pressures, the need for VSD increases. A false economy is the result and potential problems on the system over time.

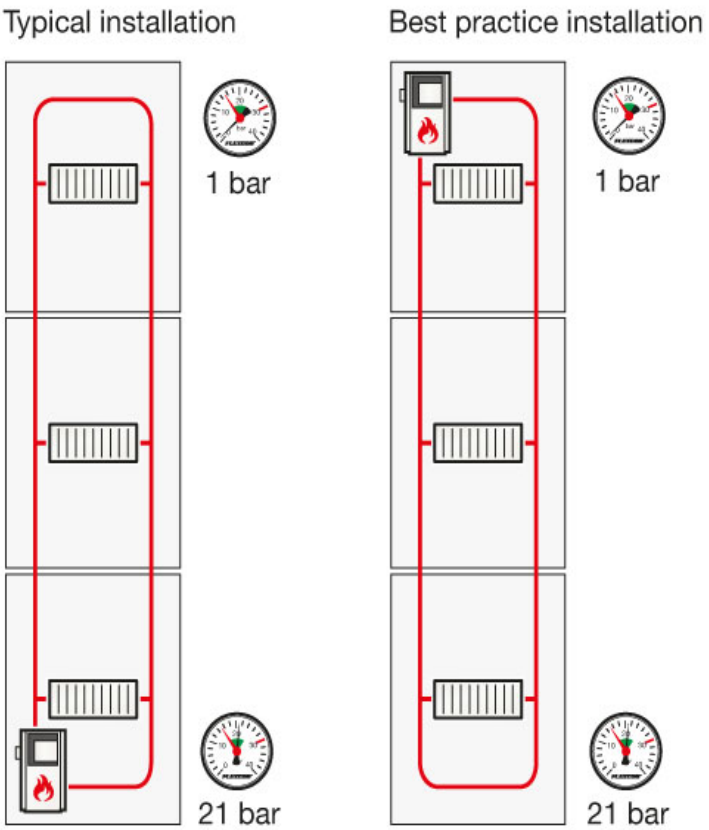
In short, solutions exist for traditional expansion equipment to be sited at the top or bottom of a system, but the sensible approach is to locate equipment as high up a system as possible. The cost savings, pressure control and knock on effects to the other system components speak for themselves.

Pressure breaks

With careful use of Plate Heat Exchangers (PHX), tall systems can be split into multiple manageable systems, each of which could then be kept below common pressure classes which would in turn reduce the cost of the associated equipment and increase the availability.

Therefore on systems that are so tall as to have pressure breaks, best practice leads us to install the expansion equipment for each pressure break at the top of each segment.





NPSH (Nett Positive Suction Head)

For modern pumps to work effectively, a suitable positive pressure is required on the suction side of the pump. This is called the nett positive suction head (NPSH) and is generally not a consideration when the pump equipment is sited at the bottom of a tall system, with the pump seeing the whole static head of the system.

However, following our overall approach of joined up thinking, the circulating pump cost may be significantly reduced if it is moved to the top of the system. In doing so it must also be considered that a slight increase in fill pressure is required at this point to make sure that the NPSH requirements of the pump are also met.

It is also worth remembering that while pump flexibles may have braided stainless coverings, the inside is flexible rubber. When the NPSH is not properly considered (on any size of system), the flexibles can collapse internally and starve the pump (and system) potentially causing significant damage and cost.

Balanced pressurisation effects

Happily traditional expansion vessels are not the only solution, balanced pressurisation equipment offers an efficient atmospheric vessel solution that is not affected by the static height of the building. Unfortunately there is no way to ignore or negate the effects of static height at the point of connection, and so the associated pumpsets, required to overcome high static pressures, are still an expensive and sometimes bespoke solution. This takes us straight back to the main purpose of this document, best practice has expansion vessels and pressurisation units, whether traditional or balanced, installed at the top of a system, especially those that have a static pressure greater than 60m.

Any further questions, please contact:

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